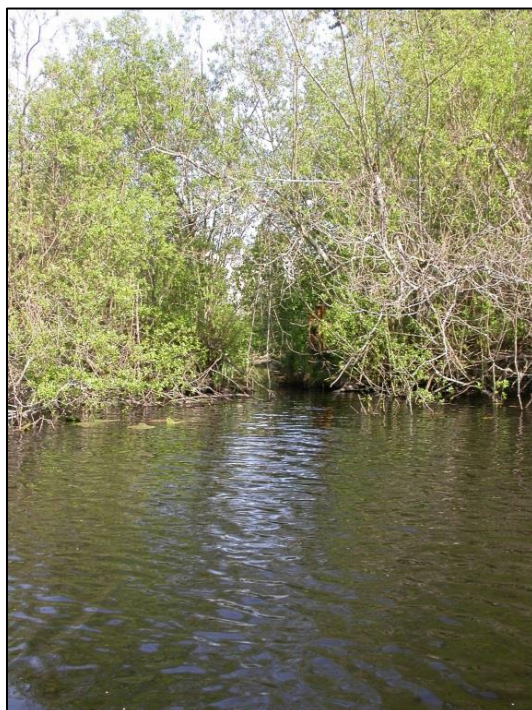# Forbes Lake Water Quality:
Water Quality Monitoring Results for Water Year 2013

February 2014

King County

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Water Quality Monitoring Results for Water Year 2013

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The City of Kirkland

Submitted by:
King County Lakes and Streams Monitoring Group
King County Water and Land Resources Division
Department of Natural Resources and Parks

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Overview

In 2006, the King County Lakes and Streams Monitoring Group (KCLSM) and its predecessor the Lake Stewardship Program began monitoring water quality with volunteers on Forbes Lake, and efforts have continued through 2013. Eight years of gathering physical and chemical data suggest that this small lake in the city of Kirkland is a mesotrophic-eutrophic lake with fair water quality.

Although there is no public access boat ramp, there are several public parcels adjacent to the lake, and opportunities exist for members of the public to access the lake at several locations, as well as to launch small boats. This presents a potential vector for the introduction of noxious weeds to the lake. Residents should keep a watch on aquatic plants growing near shore to catch early infestations of Eurasian milfoil, Brazilian elodea, or other noxious weeds.

The discussion in this report focuses on the 2013 water year. The specific data used to generate the charts in this report can be downloaded from the King County Lakes and Streams Monitoring data website at:

http://your.kingcounty.gov/dnrp/wlr/water-resources/small-lakes/data/default.aspx

Data can also be provided in the form of excel files upon request.

Further introduction and a discussion of the philosophy of the volunteer lake monitoring program and the parameters measured can be found on-line at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/waterres/smlakes/2006_Intro.pdf

1.0   WHAT WE MEASURE AND WHY

Measurements that were taken at all of the lakes in the small lakes monitoring program are discussed in this section to introduce the parameters and give context to the discussions of the data that follow.

Lake level is a relative measure of the water level that is measured daily using a staff plate installed on either a pole or a fixed height dock . These data can be used to look at the annual fluctuation of water levels in the lake, as well as response to increased water coming in due to storm events and the rate at which it drains. While most of the installed staff plates at lakes around the county are not surveyed to tie the data in with sea level, this could be done in the future to give actual elevations.

Daily **precipitation** is measured at the same time as lake water level in order to relate the lake level to inputs from the watershed. These data are collected either through a plastic rain gage provided by King County that can be emptied after reading each day or by a recording weather station if the volunteer chooses to purchase a reliable unit.

On Forbes Lake, Level II volunteers measure Secchi transparency and water temperature between May and October when they collect water samples for laboratory analysis.

Secchi transparency is a common method used to assess and compare water clarity. It is a measure of the water depth at which a black and white disk disappears from view when lowered from the water surface. Factors in the water that affect Secchi readings include the number and size of particles present, such as algae and silt, as well as water color from dissolved organic molecules. Other factors that affect the readings are the amount of glare, choppiness of the water, shade from tall trees or the boat, and variation in the vision of the observers.

Water temperature is usually measured using an alcohol-based thermometer that holds a specific temperature long enough to allow the observer to read the value after retrieving the thermometer from the water.

Phosphorus and nitrogen are naturally occurring elements necessary for growth and reproduction in both plants and animals. However, many activities associated with residential development can increase these nutrients in water beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is most often limited by the amount of available phosphorus. Increases in phosphorus can lead to more frequent and dense algae blooms – a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by cyanobacteria (bluegreen algae) that can produce toxins.

Total phosphorus (TP) and **total nitrogen (TN)** are both measured every time the level II volunteers collect water at the 1m depth. More specific forms of nitrogen and phosphorus are measured twice during the sampling period, when water is collected from 3 depths at the station: 1 m, the middle depth of the water column, and 1 m from the lake bottom.

These include nitrate-nitrite, ammonia, and soluble reactive phosphorus, and the data can be used to infer the amount of oxygen present in deep water, as well as the presence of internal loading of nutrients from the sediments back into the lake water.

The **ratio of total nitrogen to total phosphorus (N:P)** can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria (bluegreen algae), which can negatively impact uses of the lake and potentially produce toxins. When N:P ratios are near or below 25, nitrogen is as likely to be the limiting nutrient as phosphorus. Cyanobacteria may then be able to dominate the algal community due to their ability to take up nitrogen from air.

Chlorophyll-*a* concentrations indicate the abundance of phytoplankton in the lake. Although different species of algae contain varying amounts of chlorophyll, all algae use it in order to complete the photosynthetic pathway by which they store energy. For example, some cyanobacteria have other light-catching pigments and thus have relatively little chlorophyll compared to their biovolume.

Pheophytin is a product of chlorophyll decomposition and is generally measured along with chlorophyll as an indicator of how fresh or viable the phytoplankton in the sample are. Bottom sediments will contain a large amounts of pheophytin compared to chlorophyll, while actively-growing algae from surface waters will have very little pheophytin present.

A common method of tracking water quality trends in lakes is by calculating the **Trophic State Index (TSI)**, developed and first presented by Robert Carlson in a scientific paper dated 1977. TSI values predict the biological productivity of the lake based on three parameters that are easily measured: water clarity (Secchi), total phosphorus, and chlorophyll-*a.* The values are scaled from 0 to 100, which allow them to be used for comparisons of water quality over time and between lakes. If all of the operating assumptions about a lake ecosystem are met, the 3 TSI values should be very close together for a particular lake. When they are far apart in value, lake conditions and measurements should be examined to understand what special conditions exist at the lake or to evaluate the data for errors.

The Index relates to three commonly used categories of productivity:

- *oligotrophic* (low productivity, below 40 on the TSI scale - low in nutrient concentrations, small amount of algae growth);
- *mesotrophic* (moderate productivity, between 40 and 50 on TSI scale – moderate nutrient concentrations, moderate growth of algae growth); and
- *eutrophic* (high productivity, above 50 – high nutrient concentrations, high level of algae growth).

A lake may fall into any of these categories naturally, depending on the conditions in the watershed, climate characteristics, vegetation, and rock and soil types, as well as the shape and volume characteristics of the lake basin. Activities of people, such as land development,

sanitary waste systems, and agricultural practices, can also increase productivity, which is known as "cultural eutrophication."

2.0 PHYSICAL PARAMETERS

Methodical precipitation and water level records were compiled for the 2013 water year by Level I volunteers (Figure 1). Large changes occurred in level at intervals throughout the year, often related to previous rainfall. The watershed area is large relative to the surface area of Forbes Lake; therefore, surface water inflow is likely to affect lake levels more than direct precipitation on the lake's surface.

Data collected since May 2006 indicate that lake level does not vary a great deal through the year in response to seasonality, although it drops slowly during dry periods. Throughout 2013 the lake level varied around a relatively constant base that may relate to groundwater levels, with short-lived increases that can mostly be attributed to rainfall and surface water runoff. The peaks in lake level do not persist much longer than a week, with the exception of a three-week period in late February/early March.
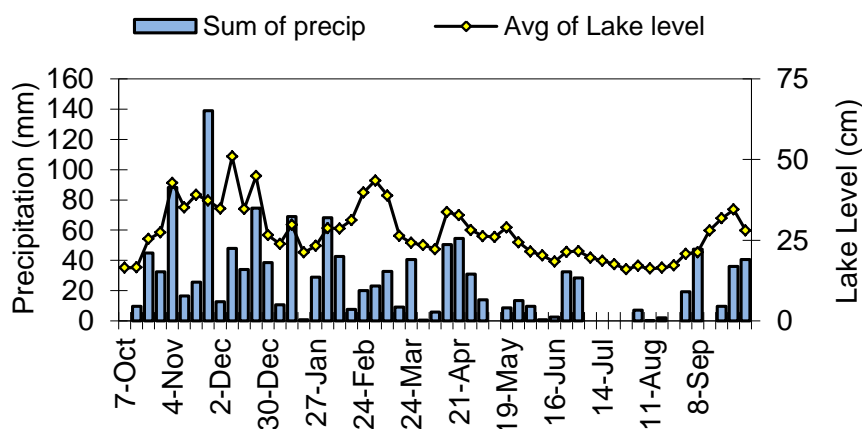

Figure 1.   Forbes Lake water level and precipitation for water year 2013.

Level II monitoring volunteers collected Secchi transparency and temperature data from early May through late October (Figure 2). Note that the Y-axis is traditionally reversed on Secchi charts to mimic looking into the water from the lake surface.

Secchi transparency from May through October ranged between 2.5 and 3.5 meters. The summer average transparency was 2.9 m, which placed it in the lower third for water clarity of the twelve small King County lakes monitored in 2013.The Secchi readings were fairly consistent throughout the summer, which may reflect the impact of water color or consistent algae concentrations. There was a slight increase in water clarity during the month of August through early September.
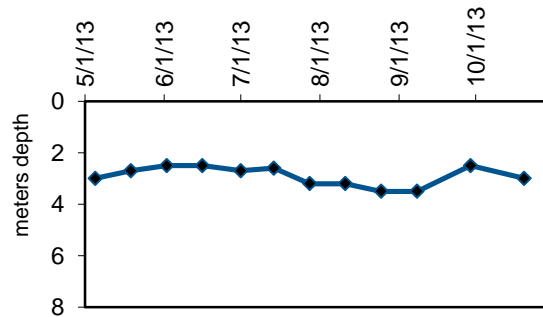
Figure 2.   Forbes Lake Secchi transparency, May – October 2013

Water temperatures at 1 m depth ranged between 12.0 to 25.0 degrees Celsius, with an average of 20.7 °C (Figure 3). Temperatures warmed in July and remained fairly stable until cooling in October, a pattern that was consistent with other lakes in the Puget Sound lowlands. Compared with measurements from 2012, lake temperature warmed earlier and remained stable for longer before dropping at the end of the summer.
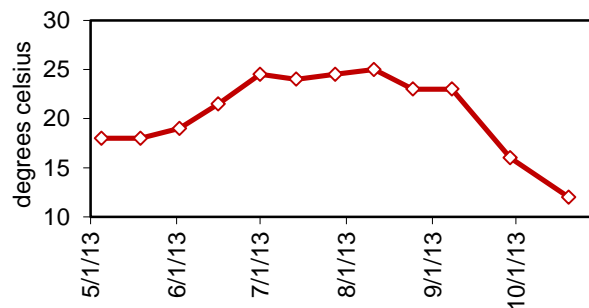

Figure 3.   Forbes Lake temperature, May – October 2013.

The average May – October temperature in 2013 was slightly warmer than the 2012 summer average and was the highest average temperature recorded since sampling began in 2006 (Figure 4). This increase may reflects the warmer, drier weather experienced in mid to late summer of 2013. Further monitoring will help determine if Forbes Lake is increasing in temperature or remaining static over time; however, currently analysis of the eight years of data do not show a significant trend in either direction.
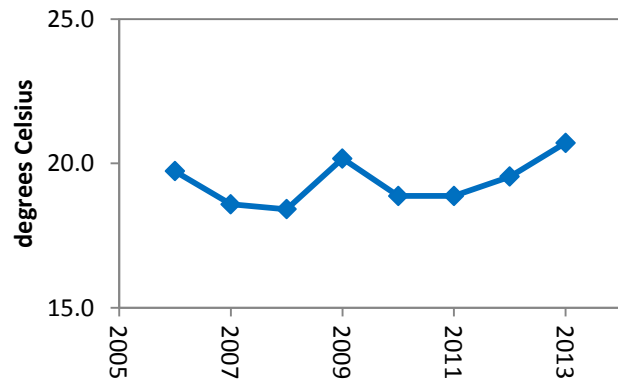
Figure 4. **Average summer temperature for Forbes Lake, 2006-2013.**

3.0   NUTRIENT AND CHLOROPHYLL ANALYSIS

Samples to be analyzed for total phosphorus (TP) and total nitrogen (TN) were collected by volunteers at a depth of one meter during the months of May through October. Samples from additional depths were collected in May and August on two dates.

Nutrient concentrations remained fairly stable throughout the monitoring period (Figure 5). Total nitrogen was highest in mid-May, declined by a small amount through July, and then increased slightly through October. Total phosphorus peaked in mid-May before stabilizing from mid-June through the end of the sampling period.
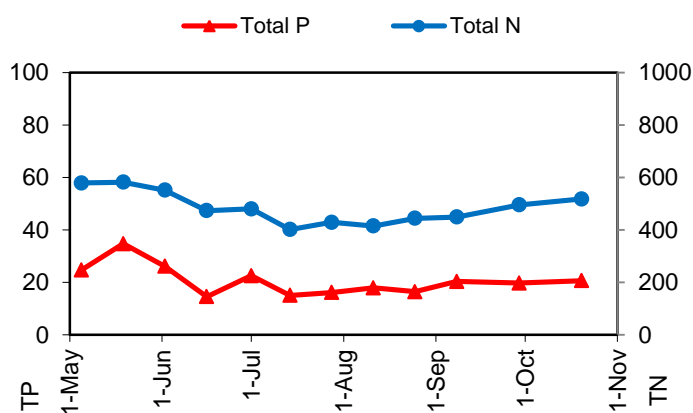

Figure 5.   **Forbes Lake Total P (TP) and Total N (TN) in µg/L, summer 2013.**

In Forbes Lake, phosphorus and nitrogen remained in relatively constant proportion to each other through the sampling period, with the N:P ratio ranging from 16.8 to 32.6 and averaging 24.3 (Figure 6). The ratio reached a maximum in mid-June, during which P was likely the limiting nutrient. However, during the remainder of the sampling period N:P levels hovered around 25, indicating that both phosphorus and nitrogen could have been co-limiting phytoplankton production, and conditions might have been favorable for competition by cyanobacteria in the phytoplankton.
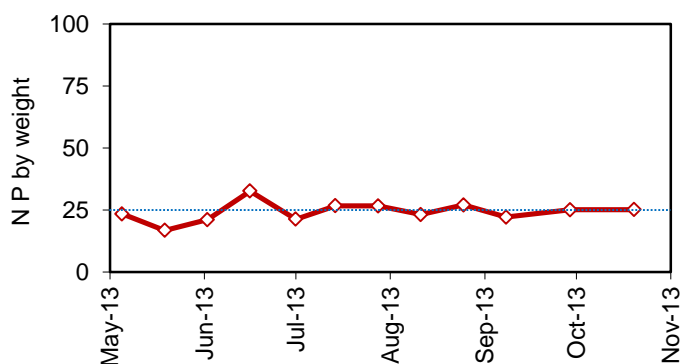
Figure 6. **Forbes Lake N:P ratios. Values at and below the blue line indicate a potential nutrient advantage for cyanobacteria.**

Concentrations of chlorophyll-*a* in Forbes Lake declined slightly from May through late July, when levels began to increase (Figure 7). There was a sharp decline in early September, followed by a major increase in October, and another decrease at the end of the sampling season. Pheophytin, a degradation product of chlorophyll, was generally at low detection levels throughout the season, but there were two peaks in pheophytin levels that coincided with drops in chlorophyll-*a*, suggesting that either algal die-off had occurred and chlorophyll pigments had degraded into pheophytin or that there might have been some problems with those particular samples.
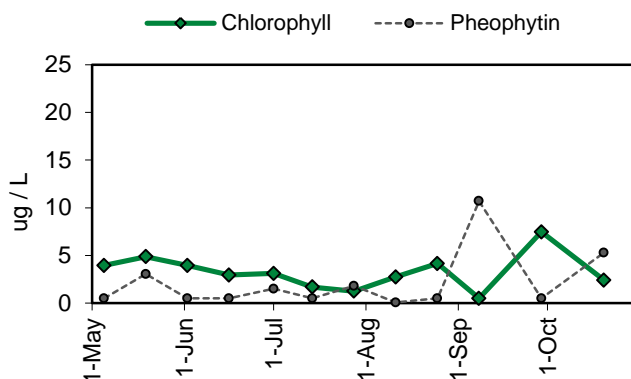

Figure 7. **Chlorophyll and pheophytin concentrations for Forbes Lake, May-October 2013.**

4.0   WATER COLUMN PROFILES

Profile samples collected in Forbes Lakes in 2013 showed similar results as those collected in 2012. Temperature data indicate that thermal stratification (temperature layering) was present by early summer and persisted through the second profile sampling event in late August (Table 1). The deeper water samples had significantly lower temperatures, as well as elevated levels of nutrients, which suggest that the hypolimnion (deep lake water below the temperature change) of Forbes Lake became low in oxygen during the summer. Anoxia (lack of oxygen) in water facilitates the release of phosphorus from sediments, resulting in higher total phosphorus and orthophosphate (OPO4) values. Higher ammonia (NH3) concentrations in the deep water samples also indicate low oxygen in deep water.

Table 1.   Forbes Lake profile results.

Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 is in absorption units. Sample values below minimum detection level (MDL) are marked in bold, red font with the MDL value.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Forbes	5/19/13	2.7	1	18.0	4.9	**3.04**	0.582	0.017	0.0347	0.0023	0.29	62.9
Forbes			4	11.0	4.7	2.27	0.652		0.0256			
Forbes			7	8.0	9.9	3.21	0.928	0.568	0.0808	0.0067		
Forbes	8/25/13	3.5	1	23.0	4.1	**0.5**	0.444	0.007	0.0164	0.0015	0.246	71.2
Forbes			4	20.0	5.6	1.1	0.378		0.0230			
Forbes			7	9.0	53.9	0.5	0.855	0.275	0.0531	0.0010		

Chlorophyll-*a* profile data indicate that algae are present throughout the water column, but at higher concentrations in deep waters than at the surface. The highest concentration of algae occurred in the seven meter sample in the August profile, which suggests that at that time there was an algae maximum in the deep water, where nutrients were plentiful and some species adapted to low light levels can take advantage of the higher nutrient availability.

The moderate values for UV254 indicate that the water of the lake is lightly colored by dissolved organic substances. The color probably is affecting the Secchi transparency values, as it does in similar lakes throughout the region. The total alkalinity values show that the water in the lake is less soft than many regional lakes and thus the lake has more buffering capacity against pH change. This may be related to the amount of development in the watershed, but could also be due to underlying geology in the area.

5.0 TROPHIC STATE INDEX RATINGS

In 2013 all three trophic State Indicators (TSI) values remained in the mesotrophic range (Figure 8). The TSI for chlorophyll-*a* has decreased over the last 3 years in a row and was the lowest since sampling began in 2006, on the threshold between mesotrophy and oligotrophy. The Secchi and phosphorus TSI values were very close together in the upper mid-range for mesotrophy.
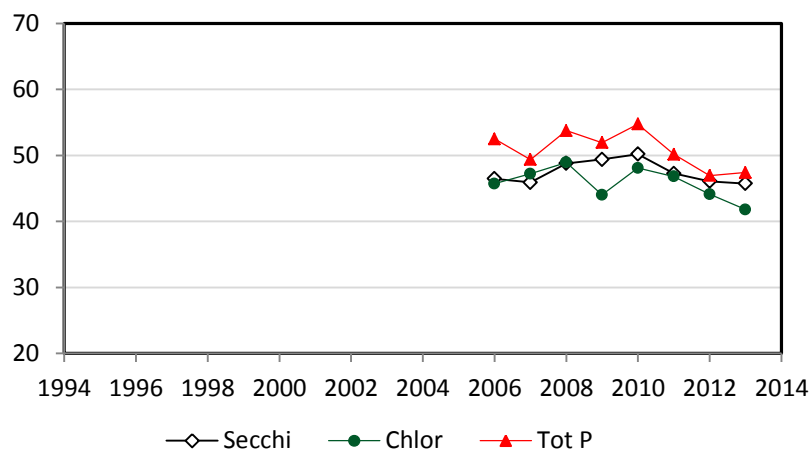

Figure 8. **Forbes Lake Trophic State Indicators over time. Chlor = Chlorophyll-*a* and Tot P = total phosphorus.**

Both the chlorophyll TSI and the phosphorus TSI currently appear to be decreasing over time (Figure 9), but the correlation coefficients of both trends are not strong (around 0.3 for each), and this indicates that annual variability is stronger than a directional trend in explaining the data distribution at this time. TSI-Secchi shows no trend to-date.
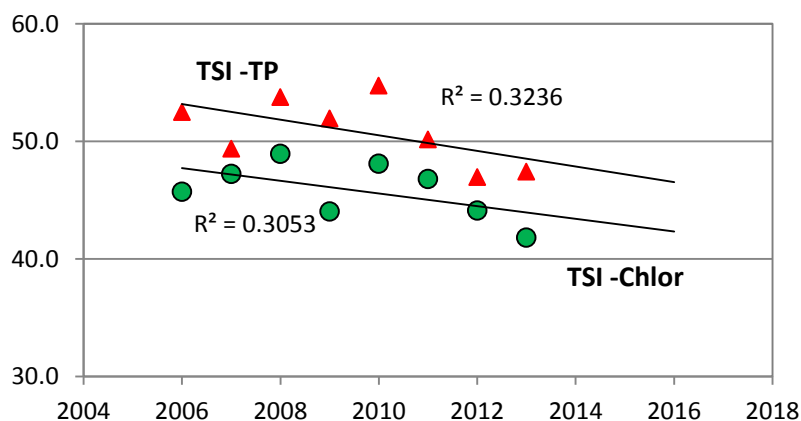

Figure 9. **Trends in TSI total phosphorus and chlorophyll-*a.***

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on monitoring data, water quality in Forbes Lake has fluctuated annually over the sampling years of 2006-2013, similar to the behavior of most aquatic systems in responding to multiple and diverse environmental variables. With eight years of data collected, trend analysis was feasible for the first time.

Certain potential trends, such as those pertaining to temperature and nutrient concentrations, could have negative impacts on Forbes Lake. Increasing temperatures in the lake might have adverse effects on plants and animals, as well as water chemistry. Low N:P ratios over the season indicate nutrient conditions favorable for nuisance bluegreen algae growth, particularly in the spring and late summer.

Neither surface water temperature nor Secchi transparency show directional trends over time. Both chlorophyll-a and phosphorus do show decreasing trends, but are not statistically robust at this time.

Continued monitoring of Forbes Lake will provide the long-term data sets that provide statistically robust determination of long term trends, as well as opportunities to identify changes occurring in the lake.

If cyanobacterial blooms are observed, partnering with King County in participation in the Washington State Department of Ecology's Algae Monitoring program is recommended to determine if algae in the lake are occasionally producing toxins.